Chapter 12 How Science Works

> *"The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' but 'That's funny...'"*
>
> — *Isaac Asimov*

As great as the impact of science has been on the lives of human beings, it still remains a mystery to the average person. Scientists are partly to blame for this sad state of affairs, failing to communicate the results of their work in ways that non-scientists can understand. The public's perception of scientists has never been accurate and it certainly hasn't been helped by the popular media. Scientists are portrayed as intelligent bumblers, like the "Doc" in *Back To The Future;* cold, emotionless automatons like "Mr. Spock" on *Star Trek;* or crazed, power-mad villains like "Doctor Octopus" of *Spider Man* fame.

The simple truth is that scientists are just normal people, like every one else on the planet. They have the same range of personalities, the same strengths and weaknesses as other human beings. They can be stubborn, willful and prideful. Because they possess a great deal of intimate knowledge about a particular area of scientific inquiry, they often think they know more than they do in other areas as well. This is usually not the case.

Though trained to be objective, careful observers, scientists can be as easy to fool as non-scientists. James "The Amazing" Randi, a well-known magician and debunker of paranormal claims, has said that scientists are easy to fool because they are trained to observe nature, and nature doesn't lie.[332] Similarly, scientists can be as vulnerable to falsehoods hyped by the media, and accepted as "common knowledge," as non-scientists. These normal human tendencies are not expected in scientists, but they are present just the same. Ask scientists who may not be familiar with climatological study at all, what they think about "global warming" and they are apt to repeat the same stories presented in the media.

This is not to say that scientists are untrustworthy, foolish or deluded—just that they are human. When scientists are asked a question about a field that they have studied, they will usually provide as honest and accurate an answer as they can. But scientists are cautious, and it can be notoriously hard to get a simple answer from them. Sometimes, you need a translator to understand that the answer is really, "I don't know."

If scientists have the same weaknesses that normal people have, what does it mean to be a scientist? How can we interpret what science has to say about hard, complicated subjects like climate change and global warming? Where did science come from in the first place? To answer these questions, we will again start with a bit of history.

The Invention of Science

Science is usually traced back to the ancient Greeks, in particular, the early Greek mathematicians and philosophers of nature. This is because their writings have been preserved and passed down, forming the basis of the western scientific tradition. But science and invention was not restricted to the Greeks or Europeans. Printing, the magnetic compass and gunpowder weapons were all Chinese in origin. We have already mentioned the history of detailed astronomical observation in pre-European Meso-America. India, Persia, and Mesopotamia all have rich traditions of early scientific inquiry. But it was science in the western tradition that fueled the Scientific and Industrial Revolutions, so we will start our story where western science started, Ancient Greece.

Archimedes of Syracuse was the greatest mathematician of his age. His contributions to geometry revolutionized the subject and his methods anticipated integral calculus 2,000 years before Newton and Leibniz. He was also a thoroughly practical man who invented a wide variety of machines including pulleys, cranes and other ingenious devices.

Archimedes was born in 287 BC in the Greek city state of Syracuse, on the island of Sicily. His father was Phidias, an astronomer. We know nothing else about Phidias other than this one fact stated in Archimedes' book, *The Sandreckoner.*

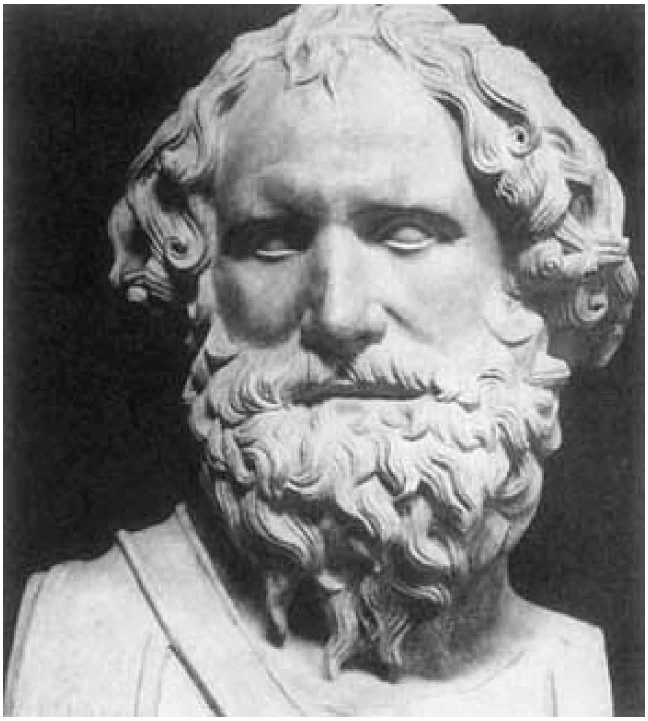

Illustration 146: Archimedes of Syracuse (287 BC-212 BC).

When he was a young man, it is thought that Archimedes visited Egypt and studied with the successors of Euclid in Alexandria. Later in life, he often sent his results to the mathematicians working in Alexandria with personal messages attached. While he was in Egypt, he invented a device known as Archimedes' screw. This is a device with a revolving screw-shaped blade inside a cylinder for pumping water. It is still used in many parts of the world today. It was this practical side of Archimedes that distinguished him from many Greek mathematicians and philosophers of his day.

Unlike philosophers, such as Socrates, Plato and Aristotle, Archimedes didn't just think up theories to explain the natural world, he actually conducted experiments to test his ideas. It was his willingness to experiment that made Archimedes the forerunner of modern day scientists. His talent for solving practical problems also led to the most repeated story told about him. It involved a crown of gold made for his friend and relative, Hieron, the ruler of Syracuse.

According to the Roman historian, Vesuvius, a new crown had been made for King Hieron in the shape of a laurel wreath. Archimedes was asked to determine whether it was of solid gold, or whether other metals had been added by a dishonest goldsmith. Archimedes knew the density of the crown would be lower if cheaper and less dense metals had been added. The simplest solution would have been to melt it down and measure its density, but he had to solve the problem without damaging the crown. While taking a bath, he noticed that the level of the water rose as he got in. He realized that this effect could be used to determine the volume of the crown, and therefore its density after weighing it. So excited by his discovery that he forgot to dress, Archimedes took to the streets naked, crying “Eureka!” —“I found it!”

The story about the golden crown does not appear in the known works of Archimedes, but in his treatise, *On Floating Bodies,* he described the law of buoyancy, known in hydrostatics as *Archimedes' Principle*. This states that a body immersed in a fluid experiences a buoyant force equal to the weight of the displaced fluid.

Archimedes died in 212 BC during the Second Punic War, when Roman forces under General Marcus Claudius Marcellus captured Syracuse after a siege that lasted more than two years. Plutarch, in his *Parallel Lives*, gives the popular account of Archimedes' death. Supposedly, Archimedes was contemplating a mathematical diagram when the city was captured. A Roman soldier commanded him to come and meet General Marcellus, but he declined, saying that he had to finish working on

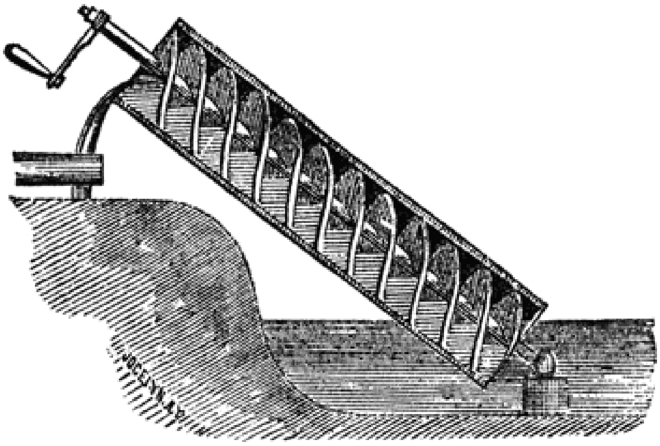

Illustration 147: Archimedes' screw. Source Chambers's Encyclopedia, 1875.

the problem. Despite orders from Marcellus that Archimedes not be harmed, the enraged soldier killed the elderly mathematician with his sword.

Ancient Roman historians wrote several biographies about Archimedes' life and works. Unfortunately, only a few copies of Archimedes' own writings survived through the Middle Ages. Those that did were an influential source of ideas for scientists during the Renaissance and Enlightenment. But before the Enlightenment swept over Europe in the seventeenth and eighteenth centuries, bringing with it the Scientific Revolution, there were many dark times. In the backward lands of Europe following the fall of the Roman Empire, one shining light was a Franciscan Friar named Roger Bacon.

Roger Bacon, also known as *Doctor Mirabilis* (Latin for “wonderful teacher”), was the most famous cleric of his time. An English philosopher, who placed considerable emphasis on empiricism, he was one of the earliest European advocates of the modern scientific method. He is often considered a modern experimental scientist who emerged 500 years before the Scientific Revolution burst upon the European mind.

Bacon is thought to have been born near Ilchester in Somerset, though he has also been claimed by Bisley in Gloucestershire. His date of birth is uncertain, the only source of information being his statement in the *Opus Tertium,* written in 1267. In it, he wrote that forty years had passed since he first learned the alphabet. It is generally assumed that this meant 40 years had passed since he matriculated at Oxford at the age of 13, placing his birth around 1214. His family was wealthy, but his parents sided with Henry III against the rebellious English barons and lost nearly all their property. Several members of the family were driven into exile.

Roger pursued his studies at Oxford and Paris, and later became a professor at Oxford. There is no evidence he was ever awarded a doctorate—the title Doctor Mirabilis was bestowed by scholars after his death. His thinking was greatly influenced by his Oxonian masters and friends. Their influence created in him a predilection for languages, physics and the natural sciences. Bacon became an early advocate of experimental science, in an age generally thought to be hostile toward scientific ideas. Later, in Paris, he met the Franciscan Petrus Peregrinus de Maricourt, whose influence led to Bacon entering the Franciscan Order.

In 1256, he became a Franciscan Friar hoping to be assigned to a teaching post, but this was not to be. Instead, his superiors imposed other duties on him. A restless spirit, he was often in trouble with church authorities for his theological writings. In 1260, the Franciscan Order forbade him to publish any work outside of the order without special permission from higher authorities “under pain of losing the book and of fasting several days with only bread and water.”[333] Despite these restraints, Bacon managed to leave behind a remarkable legacy of independent thought and inquiry.

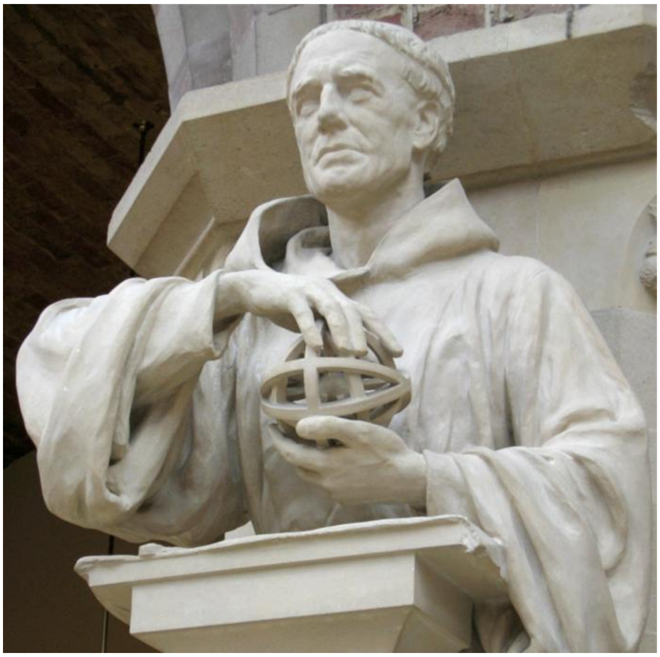

Illustration 148: Statue of Roger Bacon (c. 1214-1294), Oxford University Museum.

Bacon possessed one of the most commanding intellects of his age and made many discoveries. He performed many varied experiments, which were among the earliest instances of true experimental science. His *Opus Majus* contains treatments of mathematics, optics, alchemy, the manufacture of gunpowder, and the positions and sizes of the celestial bodies. In it, he anticipated such modern inventions as microscopes, telescopes, spectacles, flying machines, hydraulics and steam ships.

But Bacon was also a man of his time, not totally immune to the superstition and mysticism of the day. He studied astrology and believed that celestial bodies had an influence on the fate and personalities of human beings. Even so, he made discoveries that anticipated those later made by the giants of the Scientific Revolution. It was Bacon who first reported the visible spectrum of light created by a glass of water, four centuries before Isaac Newton discovered that a prism could split white light into a rainbow of colors. Reportedly, he planned to publish a comprehensive encyclopedia, but only fragments ever appeared.

Bacon is thought to have died around 1294, but the date of his death is as uncertain as the date of his birth. Two years before his death, he composed his *Compendium Studii Theologiæ*, where he set forth a last scientific confession of faith. In it, he described the ideas and principles which had driven him during his long life. According to historian Theophilus Witzel: “he had nothing to revoke, nothing to change.”[334]

When asked about the origins of modern science, many people recall the leaders of the Scientific Revolution: Galileo, Francis Bacon, and Isaac Newton or, going back at bit further, Nicolaus Copernicus or even Leonardo da Vinci. But it was from early experimentalist like Archimedes and Bacon, that modern science evolved. As Isaac Newton put it, “If I have seen further it is by standing on ye shoulders of Giants.”[335] Generations of natural philosophers gradually came to reject supernatural influences and magical explanations of the natural world. Eventually, astrology and alchemy would become astronomy and chemistry, casting off their mystical past and embracing what has come to be known as the scientific method.

The Scientific Method

According to the Miriam-Webster dictionary, the scientific method consists of “principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.” Or, as more succinctly put by Meg Urry, “Scientists observe nature, then develop theories that describe their observations.”

The scientific method is a body of techniques for investigating natural phenomena and acquiring new knowledge. It also provides mechanisms for correcting and integrating previous knowledge. The scientific method is based on gathering *empirical* evidence. This is accomplished by collecting data through observation, experimentation, and the testing of hypotheses. Empirical means simply what belongs to or is the product of experience or observation. The *Science Fair Handbook* puts it this way: “The scientific method involves the following steps: doing research, identifying the problem, stating a hypothesis, conducting project experimentation, and reaching a conclusion.”[336]

The advantage of the scientific method is that, if followed faithfully, it is unprejudiced. An hypothesis can be tested through experiment and its validity determined. The conclusions must hold regardless of the state of mind, or bias of the investigator. In fact, the cornerstone of modern science is the testability of theories. This means that a theory must make predictions about the way the physical universe behaves, so that it may be tested by investigators other than the theory's author.

The dual requirements of testability and empirical evidence disqualify mystical or religious arguments from scientific consideration. Such arguments are based on forces outside of nature, and science is only concerned with the natural world. You cannot test or measure God, so attributing some phenomenon to an act of God is not a scientific theory.

Religious truth is *revealed* to individuals, and must be taken on *faith* by others. Scientific knowledge is *discovered* through observation, and can be *tested* through experiments repeatable by anyone. Some religions are based on secret or hidden knowledge[†] that must be accepted without proof, science is

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[†] From the Greek *gnosis* (γνώσις), described as direct knowledge of the supernatural or divine. An *agnostic* is someone who denies the existence of such knowledge, believing all things are knowable without divine revelation.

based on shared knowledge open to question. Religion requires acceptance of that which is unseen (see *Hebrews 11* for an example), science is based only on that which can be observed. But, this does not mean that religion and science need to be in opposition.

Religion answers questions that science cannot, science answers questions that religion should not. Just as religious teachings cannot be viewed as a valid source of scientific knowledge, science has no authority in spiritual or ethical realms. Science is the study of nature and nature is neither moral nor immoral. Nature, at best, can be viewed as amoral, and even that is dangerously close to viewing nature as a sentient being. It is not.

Nature is a collection of physical processes, possessing no intelligence, no conscience, and no moral compass. Nature does not mourn the passing of a single creature or the extinction of entire species. There is nothing in nature that provides a scientific foundation for morality, though some have sought one. Galileo is credited with saying that religion "tells us how to go to heaven, not how the heavens go." The opposite also holds true, science does not provide moral guidance or satisfy the human longing for an underlying meaning to existence. Religion is religion, science is science and the two should never be confused.

Hypotheses, Theses and Laws

Scientific explanations are known by a number of different names. An initial scientific idea is called a *working hypothesis*, which consists of a brief statement of the explanation. After testing by experiment, an hypothesis that proves to be accurate becomes a *theory*. Sometimes theories pull together a number of hypotheses into a single, larger explanation. There is a great deal of misunderstanding about what scientists mean when something is called a theory.

Often, people will dismiss a scientific idea by saying "it's just a theory," as though a theory is just someone's opinion or something made up on a whim. This could not be more wrong. To be accepted as a scientific theory means that the ideas expressed have been examined and tested by many scientists, not just the one who first proposed it. Theories that have endured the test of time come as close to "fact" or "truth" as anything known to science. Scientists tend to shy away from absolute terms like fact and truth, because they would give the impression that a particular theory is absolute and never subject to change. In science, nothing is above challenge or immune to modification. When a theory has survived for several hundred years, and its author has departed this life, it may be elevated to being a *law*—but in science, even a law is subject to change.

This is not to say that old, well-established theories are often discarded. As new information becomes available, old theories often remain valid, but the regions over which they are valid become more narrowly defined. For example, Newton's laws of motion were not "overthrown" by Einstein's Theory of Relativity. Instead, it was recognized that Newton's laws were limited to objects traveling at velocities much less than the velocity of light.

In this way, the accumulated body of knowledge that is science continues to grow. New, better theories replace or supplement older ones. But always new theories must be in agreement with others that are accepted as valid. A new idea cannot contradict a large volume of accepted theory. Not because the weight of the old theories makes them inviolate, but because the new theory would have to offer satisfactory explanations of all the things the old theories had explained. As Marcello Truzzi[†] put it, "extraordinary claims require extraordinary proof."

Regardless of the field of inquiry, the process of investigation must be objective in order to reduce biased interpretations of results. Another basic expectation is that scientists document their work and share all data and methodology with other scientists. This is to allow other researchers to verify experimental results by attempting to reproduce them. This practice, called "full disclosure," also allows statistical measures of the reliability of these data to be established. It was lack of full disclosure by Mann, et al, that initially

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[†] Marcello Truzzi (1935-2003) Danish-American Sociologist and co-founder of the Committee for the Scientific Investigation of Claims of the Paranormal (CSICOP).

led to the flap over the "hockey stick" temperature graph promoted by the IPCC.

The Aha! Moment

Scientists' challenge is to create new theories, based on observation, that build on and are in general agreement with the existing body of scientific knowledge. In pursuit of this goal, scientists spend many years studying and learning to do research. In the American academic system, the highest degree granted is Doctor of Philosophy, or PhD, from the Latin *Philosophiæ Doctor,* meaning "teacher of philosophy." Though requirements vary, a PhD candidate must submit a thesis or *dissertation* consisting of a suitable body of original academic research. This work must be deemed worthy of publication after peer-review, and the candidate must defend the work before a panel of expert examiners appointed by the university.

Often there is coursework associated with getting the degree, but not always. If all a student desires is mastery of a particular field there is a lesser degree, the Masters degree, that can be earned with significantly lower investment of time and effort. What the Doctorate degree signifies is not mastery of a particular area of study, that is assumed, but a demonstration that the candidate can do scientific research. To earn a Doctorate an aspiring new scientist must be able to frame an hypothesis, construct experiments to demonstrate its soundness, and finally, defend his work before scientific peers. A PhD in a scientific discipline signifies that one has learned, and is a practitioner of, the scientific method.

After the years of preparation, hard work and testing, that a scientist in training is subjected to, it might be assumed that life becomes easier after earning the title Doctor. This is not the case. A working scientist will continue to formulate new hypotheses, do research, and publish papers that are reviewed by peers. Given the training and work environment, the volume of knowledge to be mastered and the rigors of the scientific method, it is easy to assume that scientists are logical, methodical individuals. This implies that the moment of discovery in science is arrived at in a slow, methodical way. More often than not, the exact opposite is true.

We began this chapter with a quote from Isaac Asimov[†] that made reference to Archimedes exclamation, "Eureka!" What Asimov meant was that, despite careful planning and experiment, it is often the unexpected, unanticipated result that brings scientific insight. Accidental discoveries have always played an important role in science.

Sir Horace Walpole[‡] coined the term *Serendipity* for such accidental discoveries. In 1754, he wrote a letter to a friend, Sir Horace Mann, describing a story that had made a profound impression on his life. The story was a "silly fairy tale, called The Three Princes of Serendip; ... as their highnesses traveled, they were always making discoveries, by accidents and sagacity, of things which they were not in quest of." [337] Serendip was an old name for Ceylon, nowadays called Sri Lanka, but then a mysterious island in the East. The tale described the fate of three princes who left their home to travel the world seeking great treasures. They rarely found the treasures they were looking for, but discovered others of equal or greater value, which they were not seeking.[338]

More than a century ago, Louis Pasteur said, "Chance favors only the prepared mind." By this, he meant that sudden flashes of insight don't just happen, but are the product of careful preparation. Pasteur was a master of experimental research. Though he wasn't greatly interested in theory, he made many important discoveries through careful observation. Pasteur didn't always know what he was looking for, but he was capable of recognizing something important when it occurred.

The lesson in all of these observations is that scientists should be as prepared as possible when investigating nature, but above all, they must keep an open mind. Deep insights can occur at the most unexpected times. Archimedes had such a moment

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[†] Isaac Asimov (1920-1992) Russian born American author and biochemist, best known for his works of science fiction and for his popular science books.

[‡] Horace Walpole (1717-1797), fourth Earl of Orford, son of Prime Minister Robert Walpole, connoisseur, antiquarian and author.

when he discovered the Archimedes Principle in his bath. Herschel must have thought "that's funny" when his thermometer unexpectedly registered increasing temperature even though placed outside of the visible spectrum of light. Moments of sudden insight are often called "Aha!" moments.

An "Aha!" moment occurs when a key concept, mechanism, or relationship suddenly comes into focus. It is the moment that scientists hope for all their professional careers—clear thoughts crystallize in "Aha!" moments. Often, scientists aren't even sure what they are looking for, as in the case of Pasteur, or as Wernher von Braun said, "Research is what I'm doing when I don't know what I'm doing."

Luigi Galvani discovered the true nature of the nervous system when an accident in his laboratory made a dead frog's legs twitch. Based on the serendipitous observations by Galvani, Alessandro Volta designed the first modern electric battery in 1800. Becquerel's discovery of radioactivity (page 121), Tombaugh's discovery of Pluto on the basis of Lowell's flawed calculations, and Fleming's discovery of penicillin when it contaminated a bacterial culture are only a few of the unexpected discoveries that have changed science.

To be able to benefit from an unexpected discovery, from serendipity, a scientist must be prepared to accept change. Experiments do not always yield the expected results, and theories must sometimes be modified or discarded when the universe reveals its true nature. Just as Luis and Walter Alvarez recognized the importance of the unexpectedly high concentration of iridium at the KT boundary, new discoveries constantly arise to challenge scientific dogma. Unfortunately, even correct new theories are seldom easily accepted.

Accepting New Ideas

In many chapters of this book, we have presented the stories of scientists and their discoveries. Though we hope the stories of Cuvier, Agassiz, Wegener, Milankovitch, the Alvarezs and all the rest have been entertaining, we had a deeper purpose for describing their labors. There is a common theme to the stories of discovery we chose to present, and that theme is how difficult it can be to overcome weak, erroneous, but commonly accepted theories.

Cuvier fought religiously inspired dogma by claiming species went extinct. It took Agassiz's theory of ice ages thirty years to overcome resistance and be accepted by the geological establishment. Wegener did not live to see his theory of continental drift proven. Both Croll and Milankovitch witnessed the initial, tentative acceptance of orbital cycles' influence on climate, only to see their theories fall out of favor. Neither lived to see the ultimate acceptance of the Croll-Milankovitch Cycles as the main driver of glacial-interglacial variation. It is hard to unseat accepted theory, compelling proof must be provided—that is the scientific way. In all of the cases presented, final acceptance depended on experimental proof of the physical mechanisms underlying the theory. This is how it should be, even if the proof takes more than a lifetime to arrive.

What is necessary for a new theory to supplant an existing one is for the new explanation to be more compelling than the old. More accurate, more demonstrable, more straightforward than the old theory. In short, the old theory must be unable to provide as good an explanation as the new one. Sometimes, as mentioned earlier, the new theory adds to the old—extending, refining or augmenting its predictions. Other times, the new theory is simpler, more elegant than the old.

In science, there is a principle known as *Ockham's Razor,* named after William of Ockham, a fourteenth century English monk and philosopher. Also called the *law of economy,* or *law of parsimony,* the way Ockham stated it was "Pluralitas non est ponenda sine necessitate," Latin for "entities should not be multiplied unnecessarily." Today, some translate this into "keep it simple, stupid," or the KISS principle. But that is an over-simplification of Ockham's rather subtle rule for judging ideas.

Illustration 149: William of Ockham (1288-1348).

Suppose there are two competing theories which describe the same phenomenon? If these theories produce different predictions, it is a relatively simple matter to find which one is better. Experiments are performed to determine which theory gives the most accurate predictions. For example, Copernicus' theory said the planets move in circles around the Sun, in Kepler's theory they move in ellipses. By carefully measuring the path of the planets it was determined that they move in ellipses—Copernicus' theory was then replaced by Kepler's.

Sometimes things are not so clear cut. The adoption of Kepler's theory of elliptical orbits was really just an improvement on Copernicus' theory. The initial adoption of Copernicus' theory was a much more radical change. It was not the shape of orbits that formed the central idea of that theory—it was what was at the center.

Before Copernicus, the widely held view of the cosmos was that described by Ptolemy[†] more than 1,400 years earlier. The Ptolemaic universe placed Earth in the center with the Sun, the planets and the stars traveling around it. His geocentric planetary system represented the universe as a set of nested spheres, with heavenly bodies embedded in the spheres. But the observed motion of some of the objects could not be represented by simple circular orbits around Earth.

For instance, the path of Mars across the sky doesn't progress in a single smooth ark. Its motion can be seen to stop, reverse course for a time, and then resume its forward progress. This *retrograde* motion cannot be reconciled with simple circular orbits in an Earth centric system. A more complicated model is needed and Ptolemy's solution was ingenious. It was possible to approximate the planets' observed motion by having them travel on smaller circular paths, called *epicycles,* imposed on top of the main orbit. Apply enough additional circles and you can come arbitrarily close to the observed path.

Illustration 150: Ptolemy's heliocentric model of the Universe.

Copernicus took a more radical approach. He placed the Sun at the center, with all the other heavenly bodies, including Earth, orbiting it. This accounted for the observed apparent motion of the planets using simple circular orbits. No complicated epicycles were needed. Under these conditions, Ockham's Razor allows us to decide which theory is best. The circles within circles theory is much more complicated than the *heliocentric* theory, so Copernicus wins. All things being equal, the simplest solution tends to be the best one.

Kepler's modification improved on Copernicus' original idea, making the orbits more accurate with only a modest increase in complexity. As Einstein said in his version of Ockham's Razor, “So einfach wie möglich und so kompliziert wie nötig,” or “As simple as possible and as complicated as necessary.” This criteria for judging competing theories is widely accepted in modern science.

Karl Popper[†] argued that preferring simple theories does not need to be justified on practical or aesthetic grounds. Simpler theories are preferred to

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[†] Claudius Ptolemaeus (ca. 90-168 AD) a Greek-Egyptian mathematician, geographer, astronomer, and astrologer in Roman Egypt.

[†] Sir Karl Raimund Popper (1902-1994) an Austrian and British philosopher of science.

more complex ones “because their empirical content is greater; and because they are better testable.”[339] Popper called this the *falsifiability criterion:* A simple theory applies to more cases than a more complex one, and is thus more easily refuted.

In light of these principles, when the CO_2 theory of climate change is examined, it is found wanting. We have shown that known mechanisms involving greenhouse warming do not account for the amount of temperature increase the IPCC's climate scientists attribute to it. The total amount of warming is not in dispute, but the magnitude of carbon dioxide's contribution is questionable. The IPCC's case fails to correctly account for all the physical observations.

The second failing of the IPCC theory is that, in order to account for the observed warming, a number of assumptions about feedback mechanisms must be made. These assumptions are not supported by experimental data or observations, yet they are included in the GCM, the computer models on which the IPCC's case rests. Because of this added baggage, the IPCC theory of human-caused global warming fails Ockham's Razor. They have multiplied their entities unnecessarily—in this case, assumptions about climatic feedback—instead of searching for more fundamental explanations for the observed temperature rise.

A huge question remains—why the climatological establishment has not looked further afield for better explanations for global warming? As we have shown in the previous two chapters, theories have been proposed by astrophysics that offer explanations for much of the warming. When taken into account, these theories reduce the amount of warming attributable to CO_2 to empirically supportable levels. Yes, humans are causing some global warming by way of greenhouse gas emissions, but the levels are much lower than those proclaimed by the IPCC reports.

Even though their existing theory is weak, climatologists cling to the belief that their computer models can accurately predict the future. Their resistance to change is similar to that faced by Agassiz, Wegener, and Alvarez. This resistance is strengthened by the fact that the proponents of change are from outside of the insular climatological community. Just as Agassiz, known for working on fossil fish, was an outsider to geologists when he proposed his ice age theory, and Wegener, a meteorologist, was an outsider when he proposed continental drift. The Alvarezs—one a physicist and the other a geologist—were outsiders to paleontology when they declared that an asteroid killed the dinosaurs. Today, climatological dogma is being challenged by outsiders.

In the words of American philosopher Charles S. Peirce, “Doubt is an uneasy and dissatisfied state from which we struggle to free ourselves and pass into the state of belief; while the latter is a calm and satisfactory state which we do not wish to avoid, or to change to a belief in anything else. On the contrary, we cling tenaciously, not merely to believing, but to believing just what we do believe.”[340] It is human nature to resist change. To accept change and embrace a new theory requires what Thomas Kuhn[†] called a *paradigm shift.*

The term paradigm shift was first used by Kuhn in his 1962 book, *The Structure of Scientific Revolutions,* to describe a change in basic assumptions within the ruling theories of science. It is more than simply changing your mind. It is more like a revolution, a sudden transformation, a sort of metamorphosis. Paradigm shifts do not just happen, but rather must be driven by agents of change. Agents in the form of determined, stubborn scientists who believe they have found better solutions than the current ones. This situation is absolutely normal for science. What is abnormal, and deeply harmful, is that the course of scientific debate has been warped by being catapulted onto the world political stage by the IPCC.

Why Consensus is Meaningless

The most commonly heard argument during public debate of the global warming question is “there is scientific consensus” agreeing with the IPCC's conclusions. This is an example of what logicians call *argumentum ad verecundiam*, Latin for

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[†] Thomas Samuel Kuhn (1922-1996) American historian and philosopher of science.

"argument from authority." Logically, this is a fallacy because the validity of a claim does not follow from the credibility of the source. Nonetheless, this type of weak argument is used all the time in advertising (e.g. "Four out of five doctors recommend..."). In simple terms, it means "all these smart people say it's true, so it is."

In science, theories are strengthened when other parties can repeat an experiment providing evidence that the theory's predictions are accurate. This helps validate the theory's correctness. But, outside of providing specific empirical data or experimental verification, asking scientists what they think is just an opinion poll.

It may be hard to understand why asking a large group of experts their opinion is an unreliable way of deciding a question. Recall the examples of scientific discovery cited in the preceding chapters. In almost all of those episodes, scientists had to fight existing opinion, the consensus of the time, to get their new theories accepted. Here are some past examples of scientific consensus:

- Consensus said the Sun, the planets and the stars orbited Earth, which was the unmoving center of the universe.
- Consensus said Earth was no more than 10,000 years old.
- Consensus said no animal species had ever gone extinct.
- Consensus said that masses of glacial ice could not have covered Europe or other temperate parts of the Northern Hemisphere.
- Consensus said that the continents were fixed in rock and could not move.
- Consensus said changes in Earth's orbit could not affect climate.
- Consensus said that the planet and its creatures were only changed by slow gradual processes, an asteroid could not have killed off the dinosaurs.

And now, in the absence of solid, definitive proof, *consensus* says that people are causing dangerous global warming. More specifically, that rising CO_2 levels are going to cause an unprecedented temperature rise that will threaten all Earth's creatures. As we have shown, the theory is uncertain, incomplete and far from definitive. Every day, new criticisms of existing climate orthodoxy arise yet claims of consensus are widespread. Many scientists are not in agreement with the IPCC's public pronouncements but, for some reason, the proponents of human-caused global warming find it important to claim unanimity exists within the scientific community.

Scientists argue—that's the way science works. Attempting to shut down debate by claiming that consensus has been reached is a sure sign that something other than science is at work. Michael Crichton, best known for his novels but also a graduate of Harvard Medical School and a former postdoctoral fellow at the Salk Institute for Biological Studies, warned of the dangers of "consensus science" in a 2003 speech:

> "Historically, the claim of consensus has been the first refuge of scoundrels; it is a way to avoid debate by claiming that the matter is already settled. Whenever you hear the consensus of scientists agrees on something or other, reach for your wallet, because you're being had. Let's be clear: the work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are verifiable by reference to the real world. In science consensus is irrelevant. What is relevant is reproducible results. The greatest scientists in history are great precisely because they broke with the consensus."

As Anatole France said, "If fifty million people say a foolish thing, it is still a foolish thing." If any number of scientists believe an erroneous theory to be correct, it is still an erroneous theory. Scientific consensus is what people fall back on when there is no clear-cut evidence or compelling theoretical explanation. To borrow a phrase from that great Texan, John "Cactus Jack" Garner,† consensus is "not worth a bucket of warm spit."

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† John Nance Garner (1868-1967) Speaker of the U.S. House of Representatives and Vice President of the United States.

The First Pillar of Climate Science

As we stated in Chapter 1, scholars often refer to the *three pillars of science:* theory, experimentation, and computation.[341] Now that we have completed our survey of the science behind Earth's climate and the natural causes of climate change we can return to analyzing the IPCC's theory of human-caused global warming. Having spent the last six chapters discussing the theories that try to explain climate change, we will begin here with the first pillar—theory.

It should be obvious from the number of times we have quoted scientists, declaring the causes of one aspect of climate change or another as “unknown” or “poorly understood,” that the theoretical understanding of Earth's climate is suspect. The detailed and tortuously defined levels of uncertainty presented in the IPCC reports themselves is an admission of fact: the theoretical understanding of Earth's climate is incomplete in fundamental ways.

In Chapter 7, we discussed the “missing sink” of carbon that has been under study for thirty years without being found. We have cited the recent realization by the European Parliament that animal emissions are more potent than human CO_2 and that, for large portions of Asia, it is particulate pollution in the “brown clouds” causing most of the atmospheric warming. We discussed statistical links between climate and the sunspot cycle that are not explained by conventional climate theory.

In Chapter 11, we discussed the astrophysical based theories, linking climate change to solar cycles and even the solar system's path through the Milky Way. These theories, yet to find wide acceptance among climatologists, have been strengthened by new findings regarding *ion initiated nucleation* (IIN) in the troposphere and lower stratosphere.[342] Recent research has also found a link between the ozone layer and global cooling. A report in the Proceedings of the National Academy of Sciences (PNAS) states that current global warming would be substantially worse if not for the cooling effect of stratospheric ozone.[343] Every day, science uncovers new relationships, new factors influencing Earth's climate. Theoretical understanding of how Earth's climate functions can only be called incomplete. Theory—the first pillar of climate science—is weak at best.

In the context of climate science, experimentation involves taking measurements of the oceans and atmosphere and collecting historical climate data in the form of proxies. In the next chapter, we will examine the second pillar, experimentation.